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THE EFFECT OF GOVERNMENT POLICY INSTRUMENTS ON THE MARKET
STRUCTURE OF THE OHIO FLUID MILK PROCESSING INDUSTRY

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The Effect of Government Policy Instruments On The Market
Structure Of The Fluid Milk Processing Industry¹

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Effect of market share and merger restrictions on seller concentration and related factors is explored using an intertemporal production-distribution model. Plant size constraints are predicated on Markovian transition probabilities. Policy instruments are found to have differing effects on size distribution, distribution patterns, costs, top 4 market share, and numbers.

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The Effect Of Government Policy Instruments On The Market
Structure Of The Ohio Fluid Milk Processing Industry

In 1968, the Neal Committee proposed restructuring of oligopolistic industries with a maximum market share of 12 percent per firm. In 1972, the Hart Bill (Industrial Reorganization Act) was introduced in the Senate declaring the possession of monopoly power to be unlawful and recommending the study of seven major industries to determine if such power existed and the abolition of any existing monopoly power. Although these proposals have never become law, they represent attempts at industry restructure after the structure has evolved. Dahl, Walters and Hoffman suggest that the evolution of industry structure should be influenced by policies designed to preserve and/or cause a "desirable" structure to evolve in lieu of allowing its natural evolution. As Dahl (p. 213) states, "Rather than waiting for firms to structurally be in the position to violate the anti-trust laws and then responding to such violations, it seems to make much more sense to me to try to identify tendencies in structure that lead to violations of the anti-trust laws and to discourage structures that have strong tendencies." This study explores the effect of two structure altering policies (market share and merger restrictions) on seller concentration and related variables.

Objective

The objective of this study is to determine the effect of and differences among antimerger, 20 percent market share, and 10 percent market share policies for the period 1972 through 1987 on fluid milk processing plant (a) numbers, (b) sizes, (c) size distribution, (d) distribution patterns, (e) processing and distribution costs associated with movement of packaged fluid milk products¹ from processing plant to wholesale or home delivery outlet, (f) market share of the top 4 and 8 plants, and (g) percentage over a 40,000 quart capacity.²

The Economic Model

The model employed is an intertemporal production-distribution model. It is an extension of the Kloth-Blake-ly model which extended the production-distribution model formulated by Martin by incorporating size economies. These models were a further extension of the Stollsteimer model and determine the optimum number, size and location of processing plants which minimize processing, assembly and/or distribution costs.

The mathematical notation of the model³ is as follows:

$$(1) \quad \text{Min}^4 \quad TC^t = \sum_{j=1}^{P^t} f(X_j^t) + \sum_{j=1}^{P^t} \sum_{K=1}^M R_{jK} X_{jK}^t$$

Subject to:

$$(2) \quad f(X_j^t) = \sum_{h=1}^U B_h^t X_h A_h$$

$$(3) \quad X_j^t = \sum_{h=1}^U B_h^t X_h$$

$$(4) \quad x_j^t \leq E^t(x_j) + \alpha \sigma_j^t$$

$$(5) \quad x_j^t \geq E^t(x_j) - \alpha \sigma_j^t$$

$$(6) \quad C \leq x_j^t \leq B$$

$$(7) \quad \sum_j x_{jK}^t = D_K^t$$

$$(8) \quad x_{jK}^t \leq \gamma D_K^t$$

The model minimizes fluid milk processing and distribution cost (EQ.1) each time period (5 year intervals), subject to constraints that introduce economies of scale (EQ. 2,3),⁵ introduce a size range for each plant (EQ. 4,5), limit minimum and maximum plant size (EQ. 6), insure supply equals demand for all consumption areas (EQ. 7), and allow the percentage of a demand area's consumption satisfied by any one plant to be varied (EQ. 8). Demand and plant size range are revised each time period.

The individual plant size range (EQ. 4,5) in time "t" is predicated on the transition probabilities (Table 1) of the Markov chain process. The derivation of the range is detailed below:

$$(9) \quad E^t(x_j) = \sum_{b=1}^R P_{ab} A_b$$

Where: $E^t(x_j)$ = expected size of plant j in time "t"; P_{ab} = probability of a plant moving from size category "a" in

Table 1. --Transition Probability Matrix For Ohio Fluid Milk Processing Plants¹

	Year t									Out of Business
	1	2	3	4	5	6	7	8	9	
1	.5									.5
2		.5	.0625							.4375
3		.09091	.63636	.18182						.09091
4			.21429	.35713	.21429					.21429
5				.14286	.42856		.14286	.14286		.14286
6					.25		.25	.5		
7					.16667	.16667	.5			.16666
8						.28571	.14286	.42857	.14286	
9									1.0	

¹Processing plant volume sizes represented by the following categories:

Category	Quarts Per Day
1	0 - 5,349
2	5,350 - 14,265
3	14,266 - 23,947
4	23,948 - 47,931
5	47,932 - 71,897
6	71,898 - 80,243
7	80,244 - 106,991
8	106,992 - 178,318
9	178,319 - 524,200

time "t-1" to size category "b" in time "t" (See Table 1);
 R = number of plant size categories; A_b = mid-point of size category b (when $b = a$, the actual size of plant j in time "t-1" will be used)

The standard deviation of the expected size of plant j in time "t" is computed as follows:

$$(10) \sigma_j^t = \left(\sum_{b=1}^Y ((A_b - E^t(X_j))^2 P_{ab}) \right)^{\frac{1}{2}}$$

Where all factors are as previously defined.

Therefore, the individual plant size range for each time period is determined as follows:

$$(11) E^t(X_j) \pm \alpha \sigma_j^t = \sum_{b=1}^R P_{ab} A_b + \alpha \left(\sum_{c=1}^Y ((A_c - (\sum_{b=1}^R P_{ab} A_b))^2 P_{ac}) \right)^{\frac{1}{2}}$$

Where $P_{ab} = P_{ac}$, $A_c = A_b$.

Merger restrictions are introduced through α .⁶ The alpha value, when adjusted, directly affects plant size potential in any given time period. To impose an anti-merger policy on an individual plant or a subset of the entire plant population, the value of alpha is decreased. This is consistent with the observation that firms will grow at a slower rate of speed given merger restrictions when the only recourse for growth is through competition in the market place. This implies that mergers tend to increase market concentration (Scherer, p. 122).

Market share restrictions are introduced through γ .⁷
 The maximum percentage of any particular county demand

allowed to be serviced by any particular plant may be adjusted from 100 percent to zero by adjusting gamma. The different model variations analyzed in this study are predicated on various parameter values of alpha and gamma (See Table 2 for selected parametric values).

Data

Area - The state of Ohio was assumed to be a closed economy (no exports or imports). With the 88 counties as demand areas, the maximum market radius for each plant is assumed to be 100 miles from processing plant to the county seat of each demand area. The base year for costs, processing plant numbers and plant locations, and initial plant size was 1972.

Consumption - The county demand for fluid milk products was the product of county population projections (for 1972 and 5 year intervals thereafter) times projected per capita demand for fluid milk products.

Processing Cost - The LAC curve in this study was based on that specified by Babb-Cobia and Devino; however, all costs (labor, containers, etc.) were updated to 1972 through the use of indexes. The new function specified in log-log form using least squares regression, is the following:

$$AC = .2357 V^{-.1393}$$
 Where: AC = dollars per quart and V = plant volume specified in quarts.

Distribution Cost - Distribution costs include those costs

Table 2.--Parametric Values Of Market Share And Merger Restrictions That Differentiate Models A Through D

Model		Parameter Values	
Alpha Designation	Government Policy (All Firms Affected)	γ	α
A	None	1.0	.65
B	20% Market Share	.2	.65
C	10% Market Share	.1	.65
D	No Mergers Permitted	1.0	.50

Table 3. --The Total Number Of Ohio Fluid Milk Processing Plants Remaining In The Industry Over Time

Year	Empirical Data	Model A	Model B (20% Market Share)	Model C (10% Market Share)	Model D (Merger)
(Plant Numbers)					
1972	102 ^{1/}				
1977		70	71	71	70
1982		66	66	69	70
1987		56	57	66	66
1992		46	47	60 ²	63 ²
1997		33			

¹Ohio Licensed Milk Dealers, Producer Distributors and Cream Stations Report, Foods and Dairy Division, Ohio Department of Agriculture, May 12, 1972.

²Estimated.

from the processing plant to the wholesale customer or, in the case of home delivery, the final consumer. They include fixed and variable truck costs, labor costs for loading and unloading cases from a truck, truck refrigeration costs, route supervisor cost, substation costs, and administrative costs associated with wholesaling. Not included are business taxes, advertising and profit.

For this study it is assumed that a 65,000 GW tractor trailer rig, hauling 14,400 quarts per load, moves the fluid milk products from the processing plant to the county seat of each county. From the county seat, both home delivery and delivery to wholesale customers are accomplished.

The actual cost functions used in this model include one for transferring package fluid milk products from the processing plant to the county seat of the demand area and a function for "in county" distribution.⁸ Total distribution cost per quart for each plant-demand area combination was the summation of the two functions resulting in

$$(12) \quad C = .0535986 + .0000302 (M)$$

where: C = dollars per quart and M = round trip mileage.

Results

This section is divided into three parts which present and compare the results of models in which the following policies were introduced: Part 1 - a market share policy compared with the use of no policy instrument; Part 2 - a

Part 1: Market Share Policy - No Policy Instrument
(Models B and C) (Model A)

Plant Numbers, Average Plant Size, Plant Size Distribution

The magnitude of market share restrictions is critical when the objective is to influence plant numbers and average plant size. A 20 percent market share restriction causes no change from the results of Model A. When the magnitude is lowered to 10 percent, the following changes occur:

(1) 18 and 30 percent more plants are in the industry by 1987 and 1992 (Table 3) than Model A, and (2) average plant size of Model C is 15 and 23 percent smaller than Model A in 1987 and 1992 (Table 4).

Even though a 10 percent market share restriction increases plant numbers and decreases average plant size, the number of industry plants still decreased 40 percent from 1972 to 1992 (Table 3) and average plant size increased 75 percent.

for the same period (Table 4). This compared favorably with Model A which had a 55 percent decrease in plant numbers by 1922 and an increase in average plant size of 128 percent over the same period.

The total number of plants and average plant size in difference among Models A and B over time can be attributed to the magnitude of market share. Market shares do not become a constraint until a certain share level is reached. Even though a high market share magnitude may not influence plant numbers and size, the remaining factors addressed in part one are affected. The results of Model C (20 percent market share) are found to be significantly different when compared to Model A.

Market share restrictions significantly alter the plant size distribution over time as follows: (1) increase the percentage of plants located in the top 6 size categories (24,000 quarts and larger), (2) decrease the percentage of plants in the lower 3 size categories (24,000 quarts and smaller), and (3) as market share decreases, the greater the difference in Model B and C results when compared with Model A. For example, 70 and 80 percent of the plants in 1987 were in the top size categories (4 to 9) in Models B and C (Table 5), whereas Model A had only 52 percent. The biggest difference is in the middle 3 categories where

Table 4. --The Average Size Ohio Fluid Milk Processing Plant Over Time

Year	Empirical Observation	Model A	Model B (20% Market Share)	Model C (10% Market Share)	Model D (Merger)
Quarts/Day					
1972	46,410 ¹ / ₁				
1977		66,795	65,854	65,854	66,795
1982		70,477	70,477	67,413	66,450
1987		84,964	83,474	72,091	72,091
1992		105,964	103,709 ²	81,239 ²	77,370 ²

¹The total daily demand in 1972 was divided by 102 plants

²Estimated.

Table 5. --The Plant Size Distribution And The Percentage Size Distribution Of The Ohio Fluid Milk Processing Industry Over Time

1977									
Category*	Model A		Model B		Model C		Model D		
	Plant No.	%	Plant No.	%	Plant No.	%	Plant No.	%	
1, 2, 3	17	24.3	20	28.2	9	12.7	8	11.4	
4, 5, 6	30	42.9	29	40.8	37	52.1	37	52.9	
7, 8, 9	23	32.8	22	31.0	25	35.2	25	35.7	
Total	70		71		71		70		
1982									
1, 2, 3	32	48.5	25	37.9	19	27.6	29	41.4	
4, 5, 6	12	18.2	19	28.8	25	36.2	18	25.7	
7, 8, 9	22	33.3	22	33.3	25	36.2	23	32.9	
Total	66		66		69		70		
1987									
1, 2, 3	27	48.2	17	30.4	13	19.7	26	39.4	
4, 5, 6	8	14.3	17	30.4	28	42.4	32	48.5	
7, 8, 9	21	37.5	22	39.2	25	37.9	8	12.1	
Total	56		56		66		66		

*Processing plant volume size represented by the following categories:

Category	Quarts Per Day
1	0 - 5,349
2	5,350 - 14,265
3	14,266 - 23,947
4	23,948 - 47,931
5	47,932 - 71,897
6	71,898 - 80,243
7	80,244 - 106,991
8	106,992 - 178,318
9	178,319 - 524,200

Table 6. --The Market Share Percentage Over Time For The
Top 4 And Top 8 Plants In The Ohio Fluid
Milk Processing Industry

	1977			
	Model A	Model B	Model C	Model D
8 Plant Market Share	42.6%	42.6%	37.2%	40.5%
4 Plant Market Share	29.5	29.5	24.1	28.0
	1982			
	Model A	Model B	Model C	Model D
8 Plant Market Share	53.7%	49.9%	40.0%	48.7%
4 Plant Market Share	38.2	35.1	25.6	34.4
	1987			
	Model A	Model B	Model C	Model D
8 Plant Market Share	62.3%	53.2%	40.5%	56.0%
4 Plant Market Share	44.1	35.4	26.0	41.1

Table 7. --Absolute Number And Percentage Of Ohio Fluid
Milk Processing Plants Over A 40,000 Quart
Capacity Per Day, Over Time

	1977		1982		1987	
	Number of Plant	Percent	Number of Plant	Percent	Number of Plant	Percent
Model A	41	58.6	30	45.5	29	51.8
Model B	44	62.0	37	56.1	40	70.0
Model C	45	63.4	41	59.4	48	72.7
Model D	46	65.7	35	50.0	31	47.0

Table 8. --The Average Processing, Average Distribution,
And Average Aggregate Total Cost For The Ohio Fluid
Milk Processing Industry Over Time

Cost Item	1977			
	Model A	Model B	Model C	Model D
	(per quart)			
Average Processing	\$.04676	\$.04678	\$.04748	\$.04722
Average Distribution	.0525	.05407	.05539	.05261
Average Aggregate	.09926	.10085	.10287	.09983
	1982			
Average Processing	\$.04514	\$.04555	\$.04698	\$.04631
Average Distribution	.05257	.05428	.05549	.05252
Average Aggregate	.09771	.09983	.10247	.09883
	1987			
Average Processing	\$.04351	\$.04471	\$.04666	\$.04527
Average Distribution	.05264	.05453	.05549	.05244
Average Aggregate	.09616	.09924	.10215	.09770

Models B and C have 30 and 42 percent of the plants and Model A has only 14 percent (Table 5). The results are similar for 1977 and 1982, except in 1977 the results of Models A and B are very similar in magnitude (Table 5).

Even though market share restrictions increase the percentage of plants located in the top 6 categories when compared with Model A, market share restrictions decrease the market share of the top 4 and 8 plants (Table 6) but increase the percentage of plants over 40,000 quarts. This decrease and increase is absorbed by a growing plant number in the middle tier (Table 7 - plant sizes 24,000 to 80,000 quarts). By 1987, 73 percent of Model C plants are over 40,000 quarts whereas Model A has only 52 percent (Table 7).

Processing And Distribution Cost

Market share restrictions increased processing and distribution costs (collectively defined as average aggregate total cost or AATC) when compared to Model A (Table 8). A 10 percent market share restriction causes a per quart increase of 0.36 (3.6 percent), 0.48 (4.9 percent) and 0.6 (6.2 percent) cents in 1977, 1982, and 1987 (Table 8). This is 1.15, 1.52 and 1.91 percent of a per quart cost of 31.4 cents. (This includes all costs associated with a quart equivalent). Over time, the distribution component of AATC decreases from 80 percent of the difference in 1977 to 48 percent in 1987,

with the absolute magnitude of the distribution cost differential being stable over time. This indicates that average processing costs become an increasingly important component of the difference.

When models B and C are compared to Model A, the cost of imposing a 10 percent market share (Model C) is 0.20, 0.26, 0.29 cents per quart (Table 8) more than a 20 percent market share (Model B) in 1977, 1982, and 1987, or approximately twice the distortion of Model B over time. The processing cost becomes a larger percentage of the difference, with the absolute magnitude of the distribution differential decreasing 27 percent from 1977 to 1987.

Plant Distribution Patterns

Market share restrictions significantly affected the distribution patterns of milk processing plants. Restrictions of 10 and 20 percent increased the number of competitors in each demand area by approximately 6.5 and 3.4 times, respectively, when compared with Model A (Table 9). As would be expected, the number of demand areas served by one plant also increased (Table 10). The 10 and 20 percent market share restrictions insure at least 10 and 5 competitors (respectively) per demand area. The minimums were almost realized in 1987.

Table 9.--The Average Number of Ohio Fluid Milk Processing Plants Supplying Products To A Demand Area Over Time

Year	Model A	Model B	Model C	Model D
1977	1.78	5.88	10.69	1.78
1982	1.73	5.67	10.55	1.77
1987	1.60	5.42	10.44	1.72

Table 10.--The Average Number of Demand Areas Supplied By A Plant In The Ohio Fluid Milk Processing Industry Over Time

Year	Model A	Model B	Model C	Model D
1977	2.24	7.28	13.25	2.24
1982	2.30	7.56	13.45	2.23
1987	2.51	8.37	13.92	2.29

Part 2: Merger Restriction Policy - No Policy Instrument
(Model D) (Model A)

Plant Numbers, Average Plant Size, Plant Size Distribution

A merger restriction will definitely affect plant numbers and average plant sizes. Model D results show that: (1) 18 and 37 percent more plants are in the industry by 1987 and 1992 (Table 3) and (2) the average plant size of Model D is 15 and 27 percent smaller than Model A during the same periods (Table 4). However, the number of plants remaining in the industry decreased 38 percent (Table 3) from 1972 to 1992 and average plant size increased 67 percent (Table 4). This compared favorably with Model A which had a 55 percent decrease in plant numbers and a 128 percent increase in average plant size by 1992.

Merger restrictions, when compared with Model A: (1) increase the percentage of plants located in the top 6 categories and (2) decrease the percentage of plants in the lower 3 size categories. For example, 61 percent of the plants in 1987 were in the top size categories (4 to 9) in Model D whereas Model A had only 52 percent (Table 5). The lower three categories showed a reverse ranking between models, Model D had 39 percent and Model A, 48 percent in the lower categories in 1987 (Table 5).

Even though merger restriction increases the percentage of plants in the top 6 categories, the market share of the top 4 and 8 plants is lower than Model A, but

increases steadily over time (Table 6). On the other hand, the percentage of plants over 40,000 quarts decreases over time and by 1987 is lower than Model A (Table 7). This information indicates that increasing plant percentage in the top 6 categories may be only temporary. Over time, it may decrease as evidenced by a percentage decrease in plants with a 40,000 quart capacity over time.

Processing And Distribution Cost

A merger restriction increases the AATC by 0.6 percent (0.06 cent) in 1977 to 1.6 percent (0.2 cent) in 1987 (Table 8) when compared with Model A. Most of this difference is processing cost which represents from 81 to 99 percent of the difference over time. The absolute value of the distribution cost difference is virtually zero. This indicates that merger restrictions do not appreciably influence distribution costs.

Plant Distribution Patterns

As expected, a merger restriction does not affect the distribution patterns of fluid milk processors. When compared with Model A, the average number of demand areas supplying a demand area for Model D are not significantly different from Model A (Tables 9 and 10).

Part 3: Merger Restriction Policy - Market Share Policy (Model D) (Models B and C)

Plant Numbers, Average Plant Size, Plant Size Distribution

The number of plants and average plant size are not significantly different between Models C (10 percent market share) and D; however, Models B (20 percent market share) and D do display a significant difference (Table 3).

On the remaining variables in Part 3 both market share models will display a difference from Model D. For example, merger restriction decreases the percentage of plants located in the top six size categories when compared to market share restrictions. Seventy and eight percent of the plants in 1987 were in the top size categories in Models B and C, whereas Model D had 61 percent even though the plant numbers were identical for Models C and D. This indicates that market share restriction encourages the growth of small and medium-sized firms. This is further substantiated by the fact that the market share models have at least 70 percent of the plants over 40,000 quarts by 1987 (Table 7) whereas Model D has only 47 percent and its plant numbers have consistently declined since 1977 (Table 7).

At the same time that market share restrictions are encouraging growth, the market share of the top 4 and 8 is 16 percentage points less for Model C when compared to Model D in 1987. This indicates that the growth is not exclusively accomplished by the top 4 and 8. In fact, a 10 percent market share restriction virtually stopped increasing concentration between 1982 and 1987 (Table 6). On the

other hand, the market share of the top 4 and 8 in Model D steadily increased over time.

Processing And Distribution Cost

Merger restriction consistently, over time, results in lower average aggregate total cost (AATC) than in the market share models with the difference increasing as market share decreases (Table 8). For example, the AATC of a 10 percent market share restriction is larger than in Model D by 3 percent in 1977 and 4.6 percent in 1987 (Table 8).

The absolute value of the distribution component of the AATC difference between market share and merger increases slightly over time; however, the percentage of the difference composed of distribution cost decreases significantly over time (from 91 percent to 68 percent for a Model C and D comparison). This indicates that processing costs increase absolutely and in percentage terms. This happens even though the number of plants in Models C and D are approximately equal.

Plant Distribution Patterns

Market share restrictions increased the number of competitors in each demand area by approximately 6.5 and 3.4 times by 1987 for Models C and B when compared to Model D (Table 9). Finally, as would be expected, the number of demand areas served by one plant also increased (Table 10).

SUMMARY AND CONCLUSIONS

The objective of this study was to compare the effect of market share and merger restriction on the market structure of the Ohio fluid milk processing industry. An intertemporal production-distribution model was developed. Individual plant size constraints for each time period were predicated on the transition probabilities of the Markov chains. Structure altering policies were imposed on the model and the effects compared and contracted.

The effects of merger and market share on six dimensions of market structure (plant numbers, average plant size, percentage of plants greater than 24,000 quart, market share of the top four and eight plants, and cost) were in the same direction when contrasted with a model on which no policy instruments had been imposed. Even though the direction was identical, magnitude differed. The remaining two dimensions (plant distribution area and the percentage of plants greater than 40,000 quart) differed in direction and magnitude.

In conclusion, the fluid milk processing industry will become increasingly concentrated without the use of policy instruments. To the extent that this is deemed unsatisfactory and a merger or market share policy is employed, the per quart cost is minimal (by 1987, a per quart cost increase of .6 percent for merger and 1.9 percent for a 10 percent market share).

Market share restriction is a better policy tool for dealing with concentration than a merger policy. A 10 percent market share constraint when compared with merger (1) increases the percentage of plants greater than 24,000 quart, (2) maintains the market share of the top four and

eight below that of merger, (3) increases the percentage of plants greater than 40,000 quart, and (4) increases the number of competitors in each market. This is accomplished at an insignificantly greater cost of 1.3 percent per quart. Concurrently, market share maintains the number of plants in the industry and average plant size at approximately the same level as merger.

The choice of the market share magnitude is critical. If the objective is to influence dimensions other than plant numbers and average plant size, a 20 percent market share should be chosen in lieu of 10 percent. A 20 percent market share, when compared with a model on which no policy instruments had been imposed, effect six of the eight dimensions analyzed in this study, excluding plant numbers and average plant size. If the objective is to influence eight dimensions and increase the magnitude of the effects, a lower market share percentage should be chosen.

Merger restrictions on all plants does not improve the competitive position of plants less than a 40,000 quart capacity, the minimum efficient size plant. Over time, the percentage of plants under 40,000 quarts increases and by 1987, the percentage is greater than when no policy is used. On the other hand, merger restrictions may be less disruptive to the participants in the marketing system than market share. If a marketer is currently supplying a greater percentage of the market than an imposed market share restriction, the marketer would be forced to decrease the market share and expand the market radius in order to sell the same output quantity. This would not occur with merger.

Finally, merger restrictions on selected large plants should be employed concurrently with market share restrictions. As a plant is forced

to expand its market radius in order to maintain or increase its daily volume, market expansion by acquisition may be attempted in lieu of internal growth through competition in the market place. Allowing small producers the opportunity to merge to increase volume to a competitive size should be considered.

APPENDIX

Footnotes

¹Fluid milk products include: fluid milk (butterfat content of 4.0 percent and less), flavored milk, buttermilk, and cream.

²A 40,000 quart capacity is considered to be the minimum optimum size plant for fluid milk processing (Parker, p. 78).

³In order to validate the model, Model A was compared and contrasted with the results of the Markov chains for the years 1977 through 1997. The criteria used were: (1) total plant numbers, (2) plant size distribution and (3) average distribution and average processing costs per quart. In summary, the model used approximates the number of plants remaining (when compared with a Markov model) in 1977 and 1997 with greater variation seen in 1982 and 1987. The size distribution generated appears to be overestimated in the lower three and top three size categories, with the middle three categories being underestimated. Finally,

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per quart processing and distribution costs generated by the model (when compared with empirical data) approximate what is, with processing cost being slightly overestimated.

⁴The model results from the separable programming algorithm can only be assumed to be a local and not a global optimum. The terms of the models are defined as:

TC^t = total processing and distribution costs in time "t", P^t = number of potential processing plants in time "t"; X_j^t = number of quarts processed by plant j in time "t"; $f(X_j^t)$ = total processing cost of plant j in time "t"; M = number of demand areas; R_{jK} = cost (in dollars per quart) of transporting fluid milk products by truck from plant j to the wholesale customer in demand area K; X_{jK}^t = quarts of fluid products transported by truck from processing plant j to the wholesale customer in demand area K; U = number of linear segments employed to approximate the nonlinear total processing cost curve (U = 10); B_h^t = this variable facilitates the introduction of the characteristics of a nonlinear function into a linear programming algorithm. Values of B_h^t are from zero to 1 inclusive. When $0 \leq B_1^t \leq 1$, $B_2 = \dots = B_{10} = 0$. When $B_1 = 1$, $0 \leq B_2 \leq 1$, $B_3 = \dots = B_{10} = 0$; ... through B_{10} ; X_h = the differential between two plant volumes. The potential plant volumes are divided into 10 unique, (non-overlapping, but contiguous) not necessarily uniform segments. $\sum_{h=1}^{U=10} X_h = 524,200$ quarts per day = Maxi-